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Title: Long-range forecasts of accumulated temperature and abnormal rainfall in relation to agricultural needs.

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Abstract: Crop husbandry can benefit from accurate long-range forecasts of accumulated temperature and from warnings of rainfall likely to significantly exceed or fall short of the seasonal average. Two-week and monthly forecasts of temperature and rainfall anomaly produced by the Synoptic Climatology Branch (Met O 13) were converted to forecasts of accumulated temperature and 'abnormal rainfall' ($\geq \pm 50\%$ of normal) for three of the climatological districts of the UK. About 70% of two-week forecasts predicted the date of a given degree-day accumulation of temperature to within $\pm$ 3 days of its actual arrival, an accuracy considered adequate for practical purposes. On the other hand, only about 45% of the monthly accumulated temperature forecasts achieved a $\pm$ 5 day accuracy. Forecasts of abnormal rainfall were not found to be sufficiently reliable to justify the issue of warnings to farmers.

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Long-range forecasts of accumulated temperature and abnormal rainfall in relation to agricultural needs

1. Introduction

Crop development is closely related to thermal time (accumulated temperature) and crop profitability is closely related to rainfall amount and its timeliness. Accurate forecasts of either or both of these variables would be useful management advice for farmers.

The application of accumulated temperature in agriculture and horticulture lies in its control of the rate of development of a crop and in the timing of characteristic growth stages at which certain operations need to be executed. When it comes to predicting the arrival of growth stages on the basis of forecast accumulated temperature, most of the practical benefit is realised if the prediction is correct to within ± 3 days for a two-week forecast and ± 5 days for a monthly forecast.

Most agronomic cultivations can tolerate moderate departures of rainfall from normal and it is only when accumulated rainfall for a two-week period is more than about 50% above or below normal that economic benefit would be gained by timely warning. So, as far as agriculture is concerned, it is the skill of a forecast in identifying large rainfall departures that is more important than its skill in predicting absolute rainfall.

The Synoptic Climatology Branch (Met.O.13) make best-estimate monthly forecasts of temperature and rainfall anomaly for 10 UK climatological districts (see Figure 1) and these anomalies can be used to derive forecasts of accumulated temperature and abnormal rainfall. This paper investigates whether these forecasts are sufficiently accurate to be issued to farmers.

2. The forecast data

The long-range forecasts issued by Met O 13 vary in length from 28 to 31 days according to the month in which the forecast starts. Two forecasts are made each month, the first starting on the first day of the month and ending on the last day of the month and the second starting on the sixteenth day of the month and ending on the fifteenth day of the next month. Output from each forecast is available for three periods, which will be denoted by the letters A, B and M. M indicates a full monthly period, A indicates the first 'half' of the monthly period and B indicates the second 'half'. Periods A and B both vary in length from 13 to 16 days but, for the purposes of this paper, their length will be taken as two weeks. The 48 monthly forecasts made in 1986/87 are investigated in this paper.

3. Accumulated temperature forecasts

The forecast temperature anomaly (α_θ) provided by the long-range forecast is an average for a district for the forecast period. This anomaly can be used to derive an accumulated temperature forecast as follows:

Let θ_F and θ_A be the forecast and actual average temperatures for a district and forecast period and let θ_N be the corresponding normal temperature.

Now $\alpha_\theta = \theta_F - \theta_N$

Let 'n' be the number of days in the forecast period. Multiplying through by 'n' gives:

$$n\alpha_\theta = n\theta_F - n\theta_N$$

In general,

$$n\bar{\theta} = \sum\theta$$

where $\bar{\theta}$ is a mean temperature and $\sum\theta$ is an accumulated temperature.

Similarly, $n\theta_F$ and $n\theta_N$ are accumulated temperatures, forecast and normal. Writing these as T_F and T_N we have:

$$n\alpha_\theta = T_F - T_N$$

$$= (T_F - T_A) + (T_A - T_N)$$

where T_A is the actual accumulated temperature $n\theta_A$.

But $(T_F - T_A) = U_F$ is the 'error' in forecasting an accumulated temperature.

$$\therefore n\alpha_\theta = U_F + (n\theta_A - n\theta_N)$$

and $$U_F = n\,(\alpha_\theta - \theta_A + \theta_N) \text{ day.degs}$$

For practical purposes the error is required in 'days' (see Introduction) and a suitable conversion of units can be achieved by dividing U_F by the corresponding normal temperature θ_N.

$$\therefore e_F = n\,\frac{(\alpha_\theta - \theta_A + \theta_N)}{\theta_N} \text{ days}$$

Values of α_θ, θ_A and θ_N were extracted from the Met.O.13 datasets and the errors (e_F) were calculated for forecast periods A and M for districts 2, 3 and 7 separately. The results are given in Table 1.

About 70% of the two-week forecast (period A) errors were within ± 3 days, which suggests that two-week forecasts of accumulated temperatures are sufficiently accurate to be issued to farmers. Only about 45% of the monthly forecast (period M) errors were within ± 5 days. In districts 2 and 3 about 90% of the period M errors were within ± 14 days and in district 7 about 90% were within ± 11 days. This level of reliability is not considered to be sufficient to justify the issue of monthly forecasts of accumulated temperature to farmers.

4. Abnormal rainfall forecasts

An occasion of abnormal rainfall was defined as one when the accumulated rainfall was equal to or greater than 50% above or below normal. Since the long-range forecast rainfall issued by Met.O.13 is in the form of a percentage of normal and the actual rainfall recorded on Met.O.13 datasets is also in this form, the comparison of forecast and actual abnormal rainfall was straightforward. The results for period A and B forecasts for districts 2, 3 and 7 are given in Table 2.

In districts 2 and 7 about 35% of the period A forecasts were correct but in district 3 only about 20% were correct. There were no occasions when abnormally high/low rainfall was forecast and the opposite actually occurred, although there was one occasion for district 3 when this very nearly happened. Although the abnormal rainfall forecasts for districts 2 and 7 were better than those for district 3 their reliability was still considered to be insufficient to justify the issue of warnings to farmers.

The period B forecasts for districts 2 and 3 were correct on only about 10% of occasions. District 7 forecasts were better with a success rate near 25%. 'Opposites' occurred in all three districts. It is evident that abnormal rainfall warnings based on the output for the second two weeks of the monthly forecast should not be issued to farmers.

Figure 1 UK CLIMATOLOGICAL DISTRICTS

TABLE 1

ERRORS (IN DAYS) IN FORECASTING ACCUMULATED-TEMPERATURE

	DISTRICT 2		DISTRICT 3		DISTRICT 7	
	Period		Period		Period	
	A	M	A	M	A	M
MEAN	-0.6	-0.5	-0.4	-0.2	-0.1	0.1
STANDARD DEVIATION	5.0	8.5	4.9	8.7	3.8	6.9
PERCENTAGE WITHIN ± 3 DAYS	67	-	71	-	73	-
PERCENTAGE WITHIN ± 5 DAYS	-	44	-	42	-	52

Note A negative mean indicates that, on average, the forecasts were late.

Table 2

FREQUENCIES OF ABNORMAL RAINFALL

Note An 'opposite' is defined as an occasion when abnormally high rainfall was forecast and abnormally low rainfall occurred, or vice versa.

District 2

		Abnormal Rainfall Occurred	Abnormal Rainfall Not Occurred	Totals	Percentage Successes
Abnormal Rainfall Forecast Period	A	5	9*	14	35.7
	B	1	12≠	13	9.7
Abnormal Rainfall Not forecast Period	A	14	20	34	
	B	14	21	35	
Totals	A	19	29	48	
	B	15	33	48	

* contains no 'opposites'
≠ contains 3 'opposites'

Table 2 (continued)

District 3

			Abnormal Rainfall Occurred	Abnormal Rainfall Not Occurred	Totals	Percentage Successes
Abnormal Rainfall Forecast	Period	A	3	11*	14	21.4
		B	2	13≠	15	13.3
Abnormal Rainfall Not forecast	Period	A	17	17	34	
		B	17	16	33	
Totals		A	20	28	48	
		B	19	29	48	

* contains no 'opposites'
≠ contains 4 'opposites'

Table 2 (continued)

District 7

		Abnormal Rainfall Occurred	Abnormal Rainfall Not Occurred	Totals	Percentage Successes
Abnormal Rainfall Forecast	A Period B	3	5*	8	37.5
		3	8≠	11	27.3
Abnormal Rainfall Not Forecast	A Period B	19	21	40	
		19	18	37	
Totals	A	22	26	48	
	B	22	26	48	

*contains no 'opposites'
≠ contains 3 opposites